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RESISTANCE OF VARIETIES OF PURTUGUESE WHEAT, TRITICUM AESTIVUM L. EM. THELL., TO THE WHEAT STEM SAWFLY

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The wheat stem sawfly, Cephus cinctus Norton, is widely distributed west of the Mississippi River. Developing larvae of these native Hymenoptera mine the stems of grass, and in the fall mature larvae tunnel to the base of the plant where they girdle the stem internally. (The point of girdling is usually ground level or not more than an inch above.) When the plants mature, the stems break where they have been girdled. Below the point of girdling, the larvae hollow out the stem and spin a hibernaculum in which to overwinter.

The sawfly, originally a borer in native prairie grasses, readily accepted wheat when the prairie grasses were converted to this crop. By 1908 the cutting and mining of the wheat stems by the larvae were causing concern in Canada and North Dakota, and by 1910 serious damage to wheat was occurring in Montana. Losses from the sawfly continued to increase in these areas, and efforts to control the insect were begun (9).[4]

In the fairly early 1920's, Schegolev (8) studied two closely related European species of grain sawflies and reported that they caused less damage when the wheat had solid stems. Then in 1934, Kemp (2) suggested breeding solid-stemmed varieties of wheat for areas in which the sawfly was a problem. Canadian research workers, therefore, collected a number of wheat varieties with solid stems for use in a breeding program and one of these, Portuguese variety S-615 (7) crossed with Apex, produced the first variety of wheat (Rescue) resistant to the sawfly. After this clue to a source of resistance was obtained, further screening of Portuguese varieties was undertaken in the United States. Seed was obtained from the USDA Small Grain Collection, Beltsville, Md., and grown in areas infested with sawflies from 1949 to 1957 and from 1961 to 1965. The varieties and selections received and tested fall into the following groups of consecutive Plant Introduction (P.I.)[5] numbers: 56119 through 56233, 94548, 94549, 94581 through 94585, 134850 through 134904, 184508 through 184639, 185197 through 185234, 185330 through 185364, 185392 through 185407, 185704 through 185720, 190988, 191484 through 192866, 203984 through 204069, 211750, 212125 through 212128, 212217, 221549 through 221551, 266893 through 266903, 268005 through 268019, and 269238 through 269252. These groups included winter and spring habit Triticum aestivum L. em Thell. and other species. However, in the present paper, we are reporting only on results obtained with 1,339 spring and intermediate growth habit types of the 1,934 T. aestivum tested.

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[4]Underscored numbers in parentheses refer to Literature Cited at the end of this report.

[5]P.I. refers to the accession number assigned to foreign introductions by the Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture.

PROCEDURE

The varieties were planted in 10-foot rows oriented at right angles to the border of the field and to the summer fallow, which was the source of sawfly infestation. They were planted on the edge of the field or strip because the adult sawfly is a weak flier and tends to oviposit in the wheat along the border first and most heavily. The orientation of rows to the edge of the field or strip allowed the sawflies to fly between them and infest the varieties evenly.

A preliminary estimate of cutting by sawflies was made the first year, and those varieties that suffered little cutting were harvested and planted the second year. In the second and succeeding years of testing, more detailed notes were taken on the replanted varieties.

Heading date was recorded when 50 percent of the stems in a 10-foot row had headed. This easily recognized and reliable phenological character was chosen to establish a relationship between plant growth and sawfly abundance because when female sawflies are abundant during early boot stage of growth, more eggs are laid. The heading date did not give us time of early boot stage, but by comparing the heading dates of the wheat varieties with that of Thatcher, a standard susceptible variety, a fairly accurate plant development and sawfly abundance relationship was established.

The stem solidness rating depended on the amount of pith in the lumen of the stem and was made by cross-sectioning the center of the top four internodes of seven stems selected at random from each 10-foot varietal row. The internodes were rated on a scale of 1 to 5, based on the amount of stem diameter that was hollow: 1=4/5; 2=3/5; 3=2/5; 4=1/5; and 5=0. The ratings are expressed as a stem solidness score, which was the sum of the average ratings for the 4 internodes and could range from 4 (a thin-walled hollow stem) to 20 (a completely pith-filled solid stem).

Girdling or cutting of the stem by larvae of the wheat stem sawfly was used as the measure of resistance. A visual estimate of the entire plant row was made in the fall after maximum cutting had occurred. However, the amount of cutting depends on the original infestation, the survival of the larvae, and the climatic conditions during the growing season. Therefore, to compare survival from year to year, we used Thatcher as a standard and applied a variation of Abbott's formula (1) as follows:

$$\frac{\text{Percent cut in Thatcher minus percent cut in variety}}{\text{Percent cut in Thatcher}} \times 100 = \text{percent control.}$$

Then the varieties were ranked on the basis of percentage of sawflies controlled. Susceptible varieties gave 25 percent or less control, intermediate varieties gave 26 to 50 percent control, and resistant varieties gave 51 percent or more control.

RESULTS AND DISCUSSION

Of the 1,339 spring and intermediate growth habit types of T. aestivum grown and rated, 31 were resistant, 100 intermediate, and 1,208 susceptible to attack by the sawfly. The resistant (R) and intermediate (I) varieties are listed in table 1 by plant introduction numbers. Evaluation is based on percentage control. However, lateness in development (days $\pm$ heading date of Thatcher) allowed the plants to escape infestation and varieties that headed 3 days later than Thatcher sustained 34 percent less cutting in some years. For this reason we dropped the evaluation one category for those varieties that headed 3 or more days later than Thatcher unless they possessed high solidness scores or high control ratings. The exceptions are noted in table 1.

Solidness is closely linked to resistance in Portuguese wheats. However, solidness fluctuated from year to year because of varying climatic conditions. For example, wheat produces less pith when days are cloudy during early growth. The average scores do not reflect these fluctuations, but varieties that were more solid usually had higher scores. For example, P.I. 94585 selections tested from 1961 to 1965 had high stem solidness scores (table 1) and were less affected by environmental conditions (6) than other varieties. Sawfly resistance in these selections may be different from that found in Rescue and in other Portuguese varieties because other Portuguese wheats used in the breeding program have not added any major genes for conferring stem solidness to those genes found in Rescue (3, 4, 5). We are studying these P.I. 94585 selections to determine whether they possess additional or different genes.

Resistance to larval cutting (expressed as the percentage control) did not parallel stem solidness scores even though there is a correlation. Probably other characteristics of the stem or pith affected the developing larvae. Since these characteristics could vary in varieties and selections, even though the solidness of two varieties was alike, percentage control could be different. However, the factors in varieties and selections that affected the developing larvae and limited the amount of cutting were associated with solidness. Further, those varieties that possess an average stem solidness score of 17 or more averaged 67.1 percent sawfly control, while those with a score of less than 17 average 54.5 percent control (table 1). The percentage control decreased when the solidness of a given variety decreased (but not proportionally). Thus though nutritional and other requirements of the larvae may also be involved, stem solidness remains the most tangible character for a quick estimate of resistance to the sawfly.

TABLE 1.--Relative wheat stem sawfly resistance in varieties and selections of Portuguese wheat, Triticum aestivum L. em Thell., that had spring and intermediate spring and winter growth habits, based on averages of several years' tests from 1949 to 1957 and from 1961 to 1965

P.I. and selection No.	Designation	Heading comparison[1]	Stem solidness score	Varietal resistance		
				Years tested	Sawfly control	Rating symbol[2]
				Number	Percent	
--	S 615----------	+2.0	17.6	5	74.2	R
56202-6 -----	Beirao----------	+2.3	19.0	5	35.6	I
-10 ----	Do[3]----------	+4.0	16.0	4	50.0	I
-14 ----	Do----------	+1.2	17.2	6	66.2	R
56206-1 -----	Ribeiro[3]----------	+3.1	16.2	8	78.0	R
-2 -----	Do[3]----------	+3.6	17.1	9	91.9	R
-3 -----	Do[3]----------	+5.6	19.4	4	89.8	R
-4 -----	Do[3]----------	+3.8	18.1	8	81.5	R
-5 -----	Do[3]----------	+3.5	18.3	5	83.0	R
56219 -------	Amarello de Barba----------	+1.5	16.0	6	50.0	I
-1 -----	Preta X Ribeiro----------	+3.6	14.6	9	63.3	I
-2 -----	Do----------	+2.7	15.5	7	47.4	I
-4 -----	Do----------	+3.3	15.1	7	54.6	I
-5 -----	Do----------	+2.5	14.8	9	42.4	I
-6 -----	Amarello de Barba----------	+1.9	16.6	8	62.5	R
-8 -----	Preta X Ribeiro----------	+2.2	14.7	10	66.7	R
-9 -----	Do----------	+2.7	16.9	5	16.9	R
-10 ----	Amarella de Barba Preta X Ribeiro-----	+2.2	16.2	4	50.0	I
-11 ----	Do----------	+2.9	16.4	7	44.4	I
-12 ----	Do----------	+2.2	16.4	10	64.9	R
56220-2 -----	Do----------	+0.6	16.4	9	61.3	R
-5 -----	Do[3]----------	+3.0	15.4	1	50.0	I
-6 -----	Do----------	+2.0	17.0	3	75.0	R
-8 -----	Do----------	+0.9	16.2	9	63.0	R
-9 -----	Do----------	+1.0	16.8	9	72.0	R
-11 ----	Do----------	+0.5	18.4	7	40.4	I

See footnotes at end of table.

TABLE 1.--Continued

P.I. and selection No.	Designation	Heading comparison[1]	Stem solidness score	Varietal resistance		
				Years tested	Sawfly control	Rating symbol[2]
				Number	Percent	
56225-3 -----	Lobeiro X Barbella----------	+2.4	18.7	5	60.0	R
-4 -----	Do[3]----------	+3.0	18.5	9	74.2	R
-8 -----	Do----------	+4.0	16.5	6	59.7	I
-10 ----	Do[3]----------	+3.3	20.0	7	49.9	I
56229-1 -----	Santa Martha X Fuscense----------	+1.1	17.0	10	60.5	R
-2 -----	Do----------	+0.7	14.5	8	57.2	R
-3 -----	Do----------	+0.8	19.2	8	67.9	R
94548 -------	Dickson 364----------	+0.8	16.0	8	38.8	I
94585 -------	Dickson 439[3]----------	+6.9	16.5	6	30.2	I
-1 -----	Dickson 439----------	-1.2	19.6	3	64.0	R
-2 -----	Do----------	-0.3	19.2	7	68.0	R
-3 -----	Do[3]----------	+4.0	17.0	1	50.0	I
-4 -----	Do[3]----------	+3.0	18.0	3	75.7	R
-5 -----	Do----------	-0.4	18.8	6	60.7	R
-6 -----	Do[3]----------	+4.0	16.5	1	50.0	I
-7 -----	Do----------	+0.5	19.0	7	80.1	R
-9 -----	Do----------	-0.5	19.2	7	76.7	R
-10 ----	Do----------	--	--	1	45.0	I
-12 ----	Do----------	-3.0	19.2	4	72.3	R
-13 ----	Do----------	--	--	1	50.0	I
-14 ----	Do----------	-1.9	20.0	4	70.8	R
134872 ------	Ferrugineum 2741----------	--	--	3	37.7	I
134886 ------	Do------- 2779----------	--	--	1	50.0	I
134887 ------	Do------- 2780----------	--	--	1	50.0	I
134888 ------	Do------- 2782----------	--	--	2	40.5	I
134893 ------	Lutescens 2676----------	--	--	1	30.0	I
134894 ------	Do----- 2678----------	--	--	4	29.0	I
134896 ------	Do----- 2680----------	+2.5	13.2	6	32.3	I
134898 ------	Do----- 2684----------	+5.0	--	4	52.5	I
134899 ------	Do----- 2686----------	--	--	1	30.0	I
134900 ------	Milturum No. 2687----------	--	--	2	35.0	I
134904 ------	Do------- 2791----------	--	--	3	33.0	I
184510 ------	Ardito----------	--	--	2	49.5	I
184511 ------	Ettore Fiermosca----------	--	--	2	29.5	I
184512 ------	Hai----------	--	--	1	50.0	I
184513 ------	Riccio X Barbella----------	--	--	1	50.0	I
184519 ------	Lutescens 3430 T No. 5----------	--	--	3	29.7	I
184520 ------	Do----- 3432----------	--	--	3	26.0	I
184521 ------	Do----- 3433----------	--	--	1	29.0	I
184523 ------	Do----- 3515----------	--	--	1	29.0	I
184524 ------	Do----- 3516----------	-0.5	--	4	45.8	I
184563 ------	Beneto----------	-4.0	--	2	49.5	I
184564 ------	Batacao----------	--	--	1	29.0	I
184565 ------	Mocho de Espiga Branca----------	--	--	2	34.5	I
184566 ------	Mocho Cabacudo----------	--	--	1	45.0	I
184567 ------	Mocho ou Rapado----------	--	--	1	50.0	I
184571 ------	Galego Rapado----------	--	--	1	29.0	I
184573 ------	Grecia----------	--	--	1	47.0	I
184574 ------	Australiano----------	--	--	2	42.0	I

See footnotes at end of table.

TABLE 1.--Continued

P.I. and selection No.	Designation	Heading comparison[1]	Stem solidness score	Varietal resistance		
				Years tested	Sawfly control	Rating symbol[2]
				Number	Percent	
184575 -----	Russia----------	--	--	2	29.5	I
184576 -----	Italo Gigliol----------	--	--	1	50.0	I
184577 -----	Alemao----------	--	--	1	40.0	I
184578 -----	Gerronde----------	--	--	1	30.0	I
184580 -----	Varrone----------	--	--	2	95.0	I
184581 -----	Manitoba----------	--	--	1	29.0	I
184588 -----	Lutescens Alef 2991----------	--	--	1	30.0	I
184589 -----	Uruguay de Espiga Branca----------	--	--	1	29.0	I
184590 -----	Lutescens Alef 2999----------	--	--	1	29.0	I
184595 -----	Milturum Alef 3031----------	--	--	1	40.0	I
184596 -----	Do--------- 3032----------	--	--	3	33.0	I
184597 -----	William Som.----------	--	--	1	50.0	I
184598 -----	Uruguay----------	--	--	1	50.0	I
184609 -----	Janetakis Sommerweizen----------	+4.0	--	3	62.0	I
184610 -----	Tremes Ruivo X Mocho de Espiga Branca--	--	--	1	29.0	I
184613 -----	Glori X Barbella----------	--	--	1	32.0	I
184620 -----	Mocho de Espiga Branca X Galega Barbado	--	--	3	29.3	I
184621 -----	Galego Rapado X Temporao de Courouche--	--	--	3	28.3	I
184629 -----	Hybride Natural Red 9----------	+2.0	--	2	49.0	I
184630 -----	Do---------- 10----------	--	--	1	29.0	I
184634 -----	Hines Kolben----------	--	--	1	47.0	I
185226 -----	----------	+1.3	16.5	3	27.3	I
190988 -----	Alentejano----------	+1.4	18.5	4	31.3	I
191495 -----	H 32 G 13399----------	--	--	3	42.3	I
191552 -----	H 16 H 13376----------	--	--	3	41.3	I
191699 -----	Gentil Rosso 6303----------	--	--	3	36.7	I
191729 -----	Fransineto 12240----------	+8.1	8.0	6	79.4	I
191735 -----	D'Espanhol 3914----------	+2.6	18.2	4	48.5	I
191750 -----	Mosolina Familia 33 2674----------	--	--	2	39.0	I
191835 -----	Arrancada A 513178----------	+0.6	18.4	8	89.6	R
191840 -----	H N Red 5 13750----------	+1.7	15.6	8	63.5	R
191844 -----	Universal II 10133----------	+1.0	--	3	49.7	I
191845 -----	Arrancada P 433696----------	+0.3	18.8	7	74.7	R
191937 -----	44 d-10131----------	+8.3	11.2	3	53.0	I
192028 -----	Amba Gheorghis----------	--	--	2	45.0	I

See footnotes at end of table.

TABLE 1.--Continued

P.I. and selection No.	Designation	Heading comparison[1]	Stem solidness score	Varietal resistance		
				Years tested	Sawfly control	Rating symbol[2]
				Number	Percent	
192262 ------	Svalov's Kolben X Schlanstedter-------	--	--	3	41.0	I
192265 ------	Roemer (Cruz de Prof.)----------	--	--	3	41.7	I
192274 ------	Kornenburger Elite----------	--	--	3	33.7	I
192275 ------	Sem Nome----------	+15.0	--	2	55.5	I
192312 ------	0729----------	--	--	3	35.7	I
192336 ------	01010 = Svea II, 1841 X Schlanstedter-	--	--	3	34.3	I
192338 ------	097162 = ExtraKolben II, 0834 X Aurore	--	--	2	49.5	I
192360 ------	Mansholts Van Hock-Sommer----------	--	--	2	50.0	I
192371 ------	Rouge de Bordeaux----------	+17.0	--	2	66.5	I
192376 ------	Aurore X 0805----------	--	--	3	36.7	I
192388 ------	321109 = Pansar II X 0921, (Kron X 3 Standard)----------	+9.0	--	2	79.0	I
192398 ------	Mars Rouge San Barbe----------	+5.0	--	3	60.3	I
192447 ------	Roma 3560----------	--	--	2	45.0	I
192605 ------	Mocho de Espiga Quadrado 2051 V 12----	+15.0	--	2	72.0	I
192670 ------	(T) P Littorio 3559----------	+8.0	--	2	70.0	I
192782 ------	Maia 9994 V 12----------	--	--	2	23.0	I
192859 ------	Gular 12424 V 1----------	--	--	1	33.0	I
192860 ------	Florence 10101 V 1----------	--	--	1	36.0	I
192866 ------	Barbado Encontrado en Fortunato-------	--	--	2	48.0	I
269239 ------	Sel. de Ruivo 269 S----------	+4.3	12.8	5	51.6	I

[1] Heading date was compared with heading date of Thatcher: + (later); - (earlier).
[2] Resistance rating symbols: R is resistant and I is intermediate between resistant and susceptible.
[3] Late-heading varieties were not dropped a resistance rating because they possessed high solidness scores or high control ratings.

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